

Acceptor Activation of Mg-Doped GaN by Microwave Treatment

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Growing a p-type GaN-based contact layer with high conductivity in semiconductor devices is extremely difficult. Mg is normally used as the p-type dopant in p-type GaN-based epitaxial layer. In this paper, a microwave treatment (MWT) different from thermal annealing (TA) [1] and low energy electron beam irradiation (LEEPI) [2] is proposed to activate the dopants in p-type GaN epitaxial layer.

The acceptor activation of Mg-doped GaN with MWT (2.45 GHz and 560 W) and with TA (730°C, 20 min) is determined by Hall-effect measurement and photoluminescence spectra. A strong 437.5 nm blue peak of the Mg-doped GaN layer with MWT and with TA compare with the as-grown sample without any treatment in Fig.1. This result is consistent with the previous studies [1,2]. The carrier concentration and the corresponding resistivity of the Mg-doped GaN layer with MWT are about $1 \times 10^{18}/\text{cm}^3$ and 1.5 ohm-cm, respectively, shown as the point A of Fig. 2, 3. For comparison, the corresponding resistivity of the Mg-doped GaN sample with TA is shown as the point B of the Fig. 2. The carrier concentration with TA also is about $1 \times 10^{18}/\text{cm}^3$. This value is nearly the same as that with MWT as evidenced by the point A and the point B shown in Fig. 3. Fig. 2 also display the resistivity reduced to about 1.45 ohm-cm for just 5 sec MWT. Even prolonging the MWT time, the resistivity of the Mg-doped GaN sample does not further decrease. These results verify that Mg-doped GaN layer are effectively activated by MWT. The activation of Mg-doped p-type GaN layer may be explained as the breaking of magnesium-hydrogen bonding due to the absorption of microwave energy.

Fig. 4. illustrates the forward voltage (V_f) and electroluminescence intensity (I_v) characteristics of an InGaN/GaN multi-quantum-well structure LED with MWT and with TA. The TA-LED demonstrates higher forward voltage than MWT-LED by 0.17 V. The electroluminescence intensities of both LEDs indicate the similar brightness. This phenomenon ensures that MWT is significantly feasible method to alleviate hydrogen passivation in Mg-doped GaN epitaxial layer.

In conclusion, we provide a novel method to activate the acceptors in p-type Mg-doped GaN layer. Using microwave treatment, the high resistivity Mg-doped GaN layer can be converted into conductive p-type GaN layer.

Reference:

- [1] S. Nakamura, T. Mukai, M. Senoh, N. Iwasa, *Jpn. J. Appl. Phys.* **1992**, 31, L139.
- [2] H. Amano, I. Akasaki, T. Kozawa, K. Hiramatsu, N. Sawaki, K. Ikeda, Y. Ishii, *J. Lumin.* **1988**, 40&41, 121.

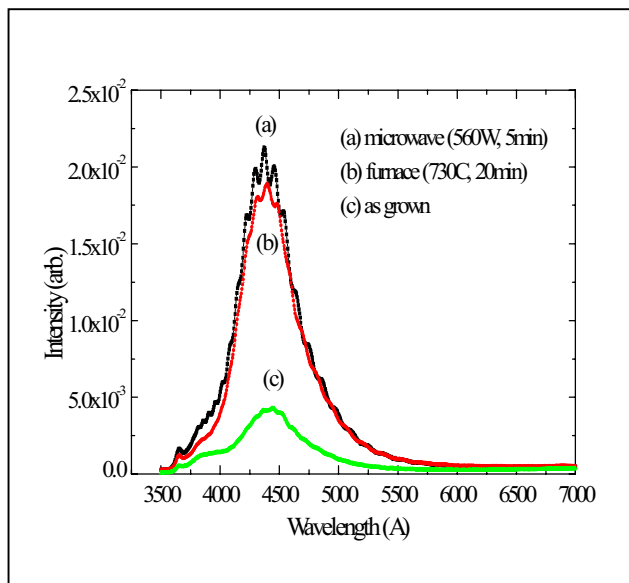


Fig.1 The PL spectra of Mg-doped GaN (a) with microwave treatment (b) with thermal annealing (c) as grown without any treatment.

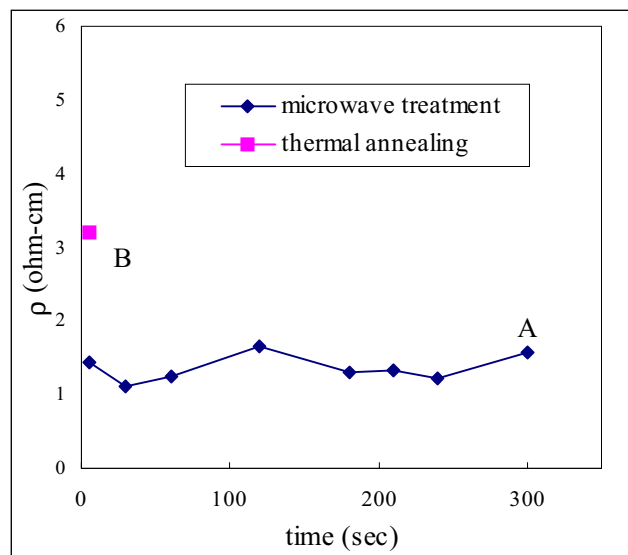


Fig.2 Resistivity of Mg-doped GaN by Hall effect measurement (a) with microwave treatment for 5, 15, 30, 60, 120, 180, 210, 240 and 300 seconds (b) with thermal annealing at 730°C, 20 min.

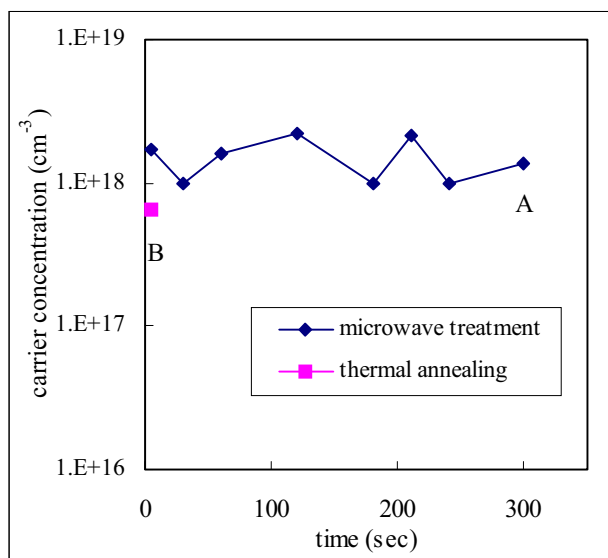


Fig.3 Carrier concentration of Mg-doped GaN by Hall effect measurement (a) with microwave treatment for 5, 15, 30, 60, 120, 180, 210, 240 and 300 seconds (b) with thermal annealing at 730°C, 20 min.

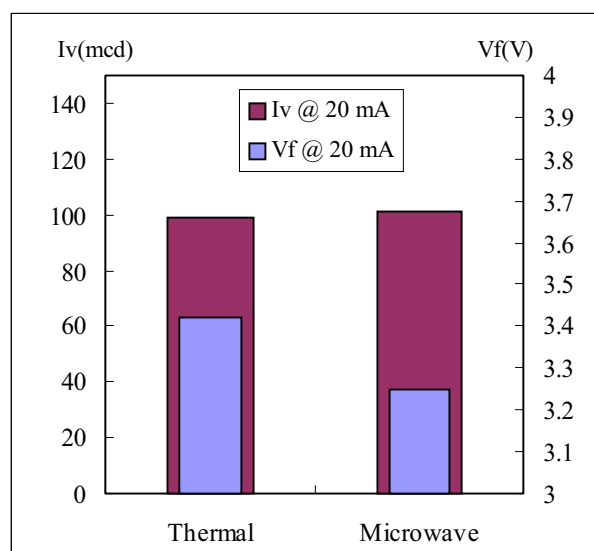


Fig.4 Forward voltage (V_f) and electroluminescence intensity (I_v) of LED with thermal annealing and microwave treatment.